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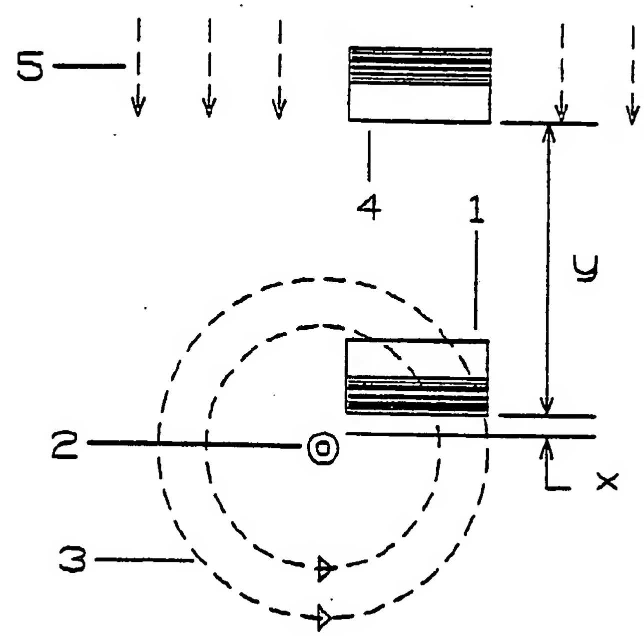

(57) Abstract

A solid state sensor (1), such as a Hall effect device, is placed in close proximity to a current carrying conductor (2). A magnetic field (3) is generated by the current flowing in the conductor (2). A second sensor (4) is placed some distance away from (1) but residing in the same vertical plane, and inverted so that for current flowing out of conductor (2) its output goes negative. When the outputs at (1) and (4) are summed the combined output will only represent flux due to the conductor, as the two measurements due to any external fields will cancel out. Modified systems may be employed with additional sensors, particularly if used in association with a pair of conductors in a current carrying system. It then becomes possible to detect any tampering with the system.

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"Magnetic field detection system"

This invention relates to a means for detecting external magnetic fields with the objective of nulling out the effect of the applied field. This is particularly useful in a solid state electricity meter. Solid state electricity meters, by virtue of their means of construction, can produce erroneous readings when subjected to a large external magnetic field.

According to the invention there is provided a magnetic field detection system comprising a pair of detecting elements positioned with respect to a current carrying conductor within the system which will create a field to be measured and linked in a circuit such that the sum of the outputs of the detectors will be zero with respect to any output components thereof caused by a large field external to the system.

The sensors can be orientated so that they detect components of the magnetic field, as created by the current in the conductor, in the same sense. Their outputs can then be added to indicate the presence of a field due to the current flowing through the single conductor. The detectors may be so orientated that they face in mutually opposite directions with respect to any external field. Alternatively they may face in the same direction, but the output of one will be fed to an invertor. Then when the outputs derived from the detectors are summed the effect caused by the external field will be nullified.

In one arrangement the two detectors may be placed in close proximity to the live and neutral conductors respectively of a current carrying system so that the fields created by the two conductors affect the detectors in the same sense, but any external field will

affect the sensors in respective opposite senses. Such an arrangement not only enables the passage of a current through the conductors to be detected, but also allows for the detection of any unauthorized tapping into one of the conductor lines which will therefore alter the normal flux fields created by the two conductors.

Solid state meters are most usually tampered with by two means, firstly by the application of a large external field and, secondly, by the injection of a fraudulent current through the live in and live out terminals. This arrangement allows for detection of attempts to tamper with a solid state electricity meter, identification of the type of tampering taking place, and the ability to calculate correctly the actual power usage while the meter is being tampered with. The various possible combinations of detectors in association with a pair of conductors are possible as will become apparent from the following description.

The invention may be performed in various ways and a preferred embodiment thereof will now be described with reference to the accompanying drawings in which:-

Figure 1 shows one embodiment of a magnetic field detection system of this invention comprising a pair of solid state detectors positioned with respect to a current carrying conductor in a large external field;

Figure 2 shows a circuit which will combine the outputs of the two solid state detectors of Figure 1;

Figure 3 graphically shows the effect of the overall system of Figures 1 and 2;

Figure 4 illustrates a modification of the system shown in Figure 1;

Figure 5 graphically shows the effect of the overall system of Figure 4 used in combination with Figure 2;

Figure 6 is a further modification of the system of Figure 1 used in association with a pair of current

carrying conductors;

Figure 7 shows a system of this invention using three sensors positioned with respect to live and neutral conductors within a solid state electricity meter; and

Figure 8 shows yet another system of this invention using two pairs of solid state sensors positioned with respect to live and neutral conductors within a solid state electricity meter.

With reference to Figure 1 a solid state sensor 1, such as a Hall effect device or a magneto resistive sensor, is placed in close proximity to a current carrying conductor 2. A magnetic field 3 is generated by the current flowing in the conductor 2. The sensor 1 is orientated so that for current flowing out of the end of the conductor 2 its output goes positive for this argument. A second sensor 4 is placed some distance away from 1 but residing in the same vertical plane, and inverted so that for current flowing out of conductor 2 its output goes negative. If the ratio of $\underline{y}$ to $\underline{x}$ is 10:1 then, since the flux density varies inversely with distance from the surface of conductor 2, the magnitude of the output of sensor 1 will be 10 times greater than that of sensor 4.

Considering the case of a large external field 5 such as would be produced at the centre of a one metre diameter coil energised at 400 Ampere turns, the lines of force of which are shown, the effect on 1 will be to produce a negative output and at 4 a positive output. The magnitude of the outputs will be equal to all intents and purposes.

With reference to Figure 2, if the outputs of 1 and 4 are summed, the values of resistors 6 and 7 being equal, the output of an amplifier 9 will be given by the following formula:-

$$V(9) = \frac{V(1).R(8)}{R(6)} + \frac{V(4).R(8)}{R(7)}$$

where V(1) is proportional to the flux due to the conductor plus the external field, and
V(4) is proportional to the flux of the external field,

Hence the output V(9) will only represent flux due to the conductor.

With reference to Figure 3 the above argument is shown graphically. Trace 10 represents a flux with peak values of +/- 1.5 mT induced at the surface of 2 by a true current in 2. Trace 11 indicates the presence of a large external field of +/- 0.5 mT in antiphase to the field induced by the current in 2. Hence 12 indicates the output of 1 which sums the field due to the current in 2 and the large external field. Trace 13 indicates the output of 4 in response to the external applied field. Trace 14 indicates the corrected signal at the output of the amplifier 9, which represents the original true flux due to the current in 2.

In the arrangement shown in Figure 4 the second sensor 4 is placed at a distance equal to the distance of sensor 1 from the conductor 2 but diametrically opposite to sensor 1 and so orientated as to detect the field 3 in the same sense as sensor 1, but to detect the field 5 in the opposite sense. Since the external flux 5 has an equal and opposite effect on sensors 1 and 4 the external effects are balanced out and the derived output is effectively twice that of one sensor in isolation.

The outputs of the sensors 1 and 4 are summed in the circuit of Figure 2, the values of resistors 6 and 7 being equal or set to balance the performance of the sensors 1 and 4. The output of the amplifier 9 will

only represent the flux due to the conductor. This can be seen from Figure 5 where the argument is shown graphically. Traces 10, 11 and 12 are as before Trace 15 indicates the output of 4 which sums the field due to the current in 2 and the large external field 5. Trace 16 indicates the corrected signal at the output of amplifier 9 which represents the original true flux due to current in 2 (but at double the amplitude).

Figure 6 shows the two detectors 1 and 4 positioned with respect to the live and neutral conductors 2 and 17 respectively of a current carrying system. In both cases the sensors 1 and 4 are orientated so that the magnetic fields 3 and 18 generated by the current cause the two sensors to go positive for the arguments illustrated. Both sensors lie in the same vertical plane, but since they are inverted with respect to each other the sensor 1 will produce a negative output component due to detection of a large external field 5, whilst the sensor 4 produces a corresponding positive output component. The magnitude of these output components will, to all intents and purposes, be equal. Consequently, if the outputs of the two detectors 1 and 4 are summed, (such as in the circuit of Figure 2), the corresponding summed output will represent only the combined flux due to the fields caused by the two conductors 2 and 17, the effect of the field 5 having been nullified.

The arrangement shown in Figure 6 not only allows the passage of a current through the system incorporating the two conductors 2 and 20 to be detected, but also enables unauthorized tapping into one of the conductor lines to be detected as this will alter the normal levels of the flux fields and create an abnormal summed output from the detector circuit.

With reference to Figure 7 two detectors 1 and 4 are

placed in close proximity to the live 2 and neutral 17 conductors, whilst a third detector 19 is placed some distance from either, for example directly between the two conductors. The two detectors 1 and 4 in close proximity to the conductors 1 and 17 will normally produce outputs which are equal in magnitude. The third detector 19 will normally produce no output. Upon application of a fraudulent current to the live or neutral conductors the outputs of detectors 1 and 4 will be different. Upon application of a large external field 5 the outputs of detectors 1 and 17 will be similarly affected whilst the output of detector 19 will be affected in the opposite sense, which indicates an attempted fraud, but the output of detector 19 can be used to correct automatically the erroneous output of detectors 1 and 17 via a suitable amplifier. Hence by use of the above two mechanisms the nature and magnitude of an attempted fraud can be determined and steps can be taken to correct this.

With reference to Figure 8, two pairs of detectors 1, 4 and 1A, 4A monitor the fields around the live 2 and neutral 17 conductors within a meter. Each pair responds in a similar manner to an external field 5, such that the summed outputs of each pair are not affected by the external field, whilst each member of each pair is affected in an opposing manner. With regard to the local field of the conductor each member of each pair is additive.

Upon application of a large external field 5 detectors 1 and 1A will generate similar signals as will 4 and 4A. Hence the difference between the output of 1 and 1A will be zero, as will the difference between 4 and 4A, while the sum of 1 and 4 will be zero, as will the sum of 1A and 4A. Hence if a magnitude difference occurs between 1 and 1A or between 4 and 4A, but the

aforementioned criteria apply, then this is a unique indication of the application of an external field, but this external field will be corrected for automatically.

Upon application of a fraudulent current then the magnitude of the outputs of detectors 1 and 4 will be different from the magnitude of the outputs of detectors 1A and 4A. This is uniquely indicative of a fraudulent current being applied.

With either of the schemes shown in Figure 7 and Figure 8 the case of a fraudulent current results in a difference being detected in the live and neutral currents. It is possible by suitable circuitry to correct for the fraud in the event of minor currents less in magnitude than the real current, and in the event of major currents greater than the real current to increase the charges to the consumer by up to twice the attempted fraud. This is done by summing the detected live and neutral currents to create a combined signal, and also taking the difference between the live and neutral currents. If the magnitude of the sum is added to the magnitude of the difference, then the overall effect is to multiply the largest current in a fraud situation by two. For instance if the current in a meter is 3A detected in live and neutral then the sum is 3A + 3A = 6A, and the difference is 0; hence sum plus difference = 6A, which is correct. If the live current is reduced by fraud to 2A then the sum is now 5A and the difference is 1A, hence sum plus difference is 6A which is correct. In the event of negative fraudulent currents so that the live current is say -20A and the neutral remains at 3A then the sum is 17A and difference is 23A, making a total of 40A.

The sensors 1 and 4 are advantageously positioned radially of the conductors. Furthermore, where the sensors are to be integrated into chips, the chips could

be formed with suitable cut-outs to receive the proposed conductor(s) in precisely the required positions(s). Another possible modification is to provide the two sensors so that they face in the same sense relative to the field 5, but incorporate in the circuitry an invertor for one of the (amplified) outputs from the sensors, so as to achieve the desired nullification of the flux measurement from the field 5, when the two outputs are combined later.

Although the invention is particularly defined by the following claims, it is to be understood that it includes any inventive combination of the features set out in the preceding description.

CLAIMS

1. A magnetic field detection system comprising a pair of detecting elements positioned with respect to a current carrying conductor within the system which will create a field to be measured and linked in a circuit such that the sum of the outputs of the detectors will be zero with respect to any output components thereof caused by a large field external to the system.

2. A detection system according to Claim 1, wherein the two detectors are placed so that one detector is in close proximity to the conductor whilst the other is placed some distance away from the first, and either the other detector resides in the same vertical plane and is inverted, or the other detector faces in the same direction and one of the detectors is connected to a separate invertor.

3. A detection system according to Claim 1, wherein the two detectors are placed in diametrically opposed positions relative to the conductor but in positions inverted with respect of one another, or positioned in the same sense with one of the detectors connected to a separate invertor.

4. A detection system according to Claim 3, wherein a second current carrying conductor is provided with a further pair of detecting elements in an identical array and the pairs of detecting elements are linked to enable the measured fields in the two conductors to be compared.

5. A detection system according to Claim 1, wherein a second current carrying conductor is provided and the detectors are respectively placed in close proximity to one or other of the two conductors such that the two detectors reside in the same vertical plane, either in positions inverted with respect to one

another or positioned in the same sense with one of the connectors connected to a separate invertor.

6. A detection system according to Claim 1, wherein a further detecting element is positioned with respect to a second current carrying conductor in the system, and the three detecting elements are linked together in the circuit to enable their outputs to be compared.

7. A detection system according to any one of Claims 1 to 6, wherein the detectors are Hall effect devices or magneto resistive sensors.

8. A method of detecting magnetic fields using a system as defined in any one of Claims 1 to 7, wherein the outputs from the detectors are compared to enable magnetic effects due to a large external field to be cancelled out, and/or to enable changes in the normal output from the conductors to be registered.

FIGURE 1

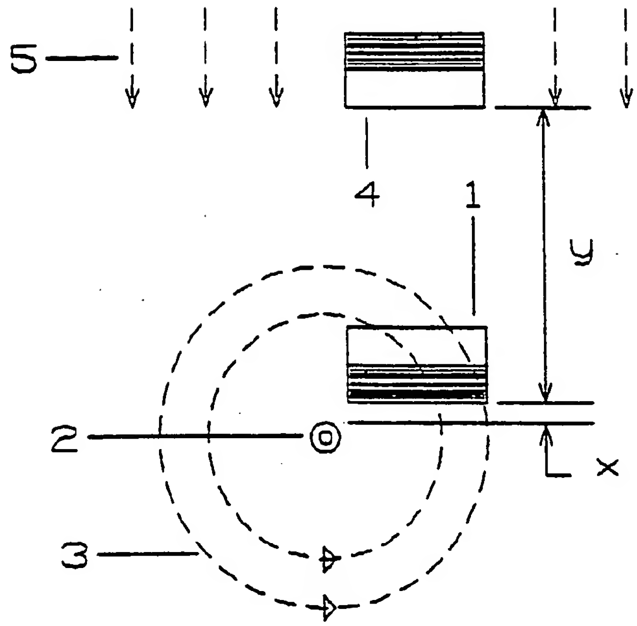


FIGURE 2

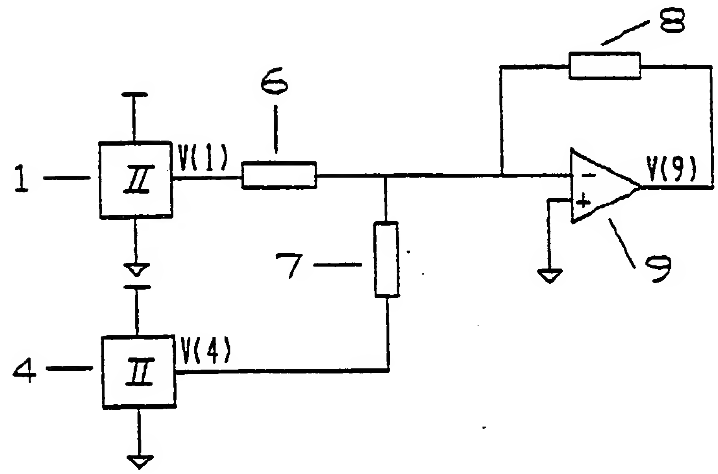


FIGURE 3

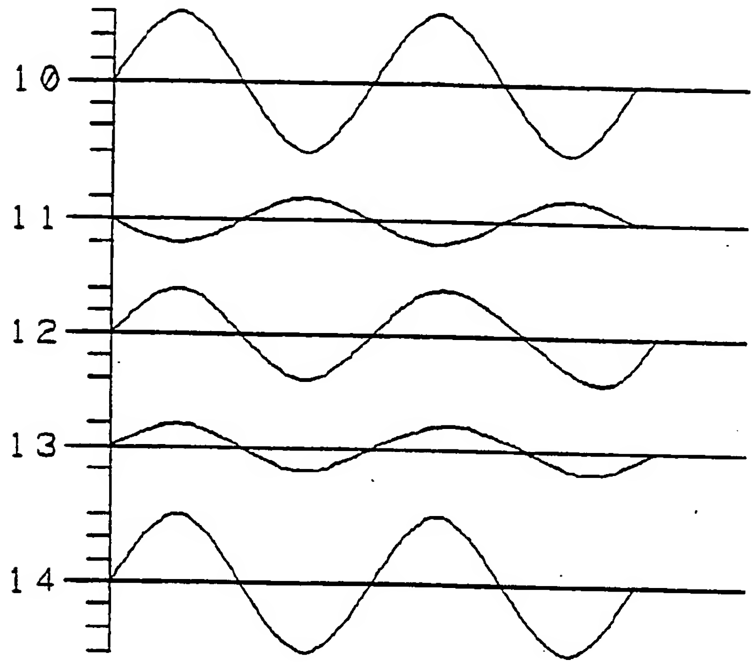


FIGURE 4

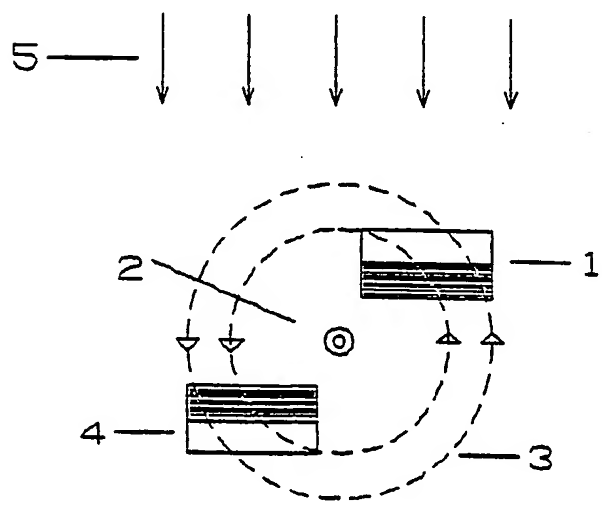


FIGURE 5

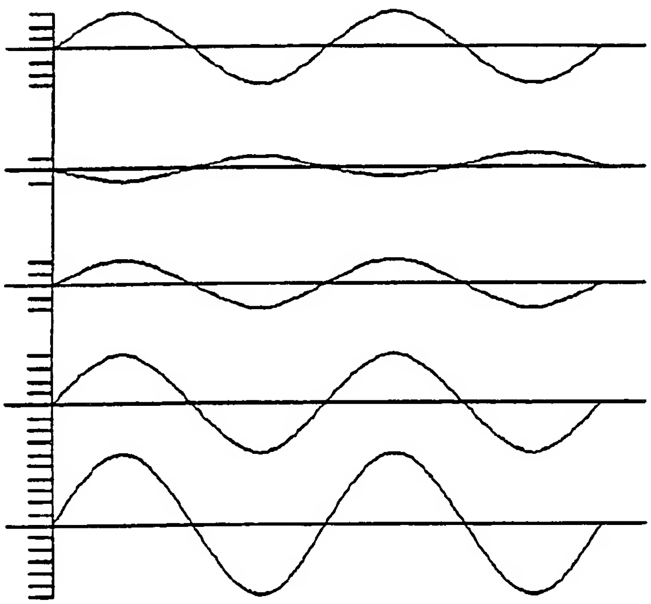


FIGURE 6

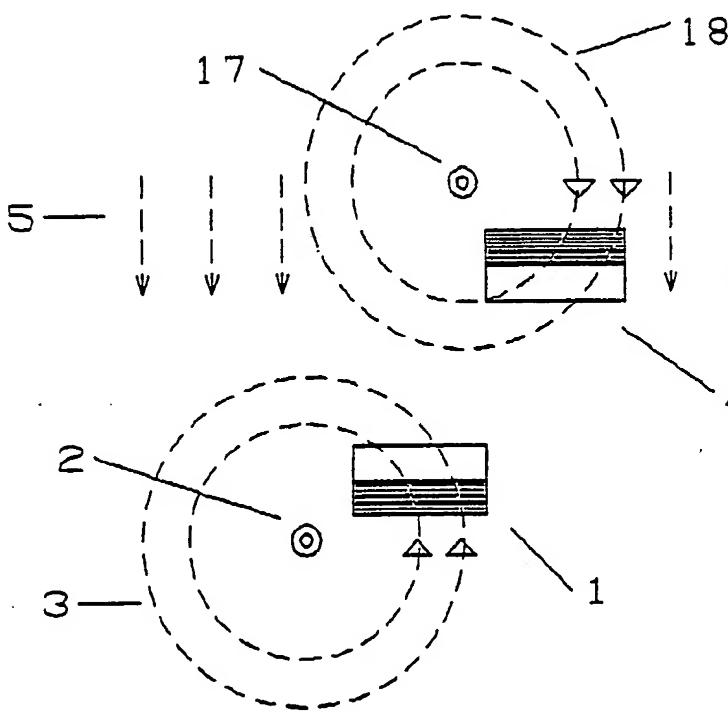


FIGURE 7

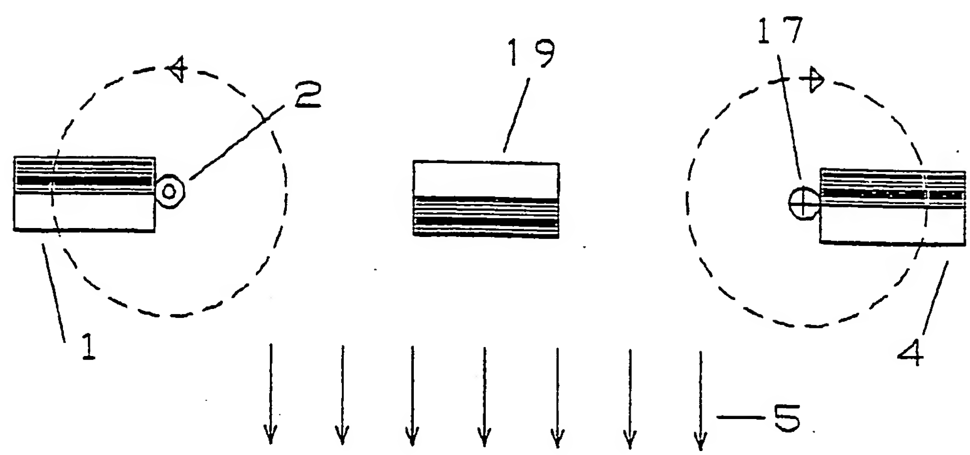
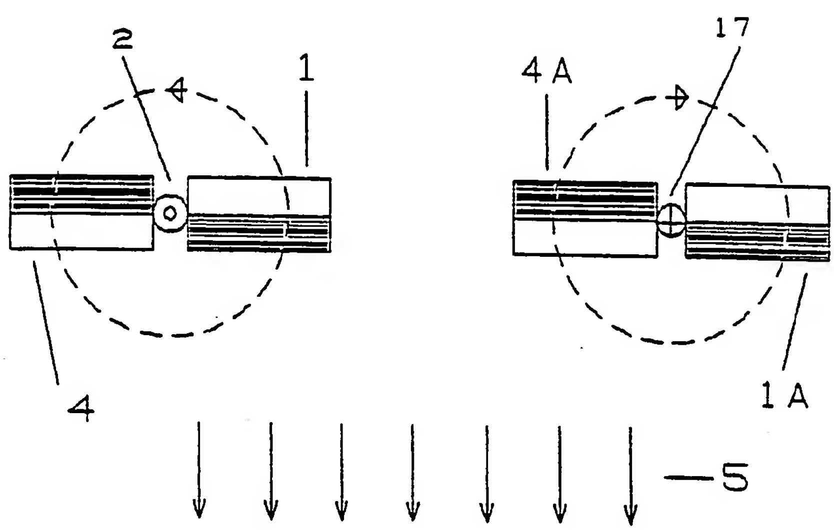


FIGURE 8



INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 89/00426

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: G 01 R 33/025, G 01 R 11/24

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	G 01 R, G 01 V

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	Patent Abstracts of Japan, volume 5, no. 201 (P-94)(873), 19 December 1981, & JP, A, 56122978 (SHIMAZU SEISAKUSHO K.K.) 26 September 1981 --	1
A	EP, A, 0122899 (SCHONSTEDT INSTRUMENT CO.) 24 October 1984 see abstract; figure 1 --	1
A	US, A, 3932813 (GALLANT) 13 January 1976 see column 3, line 55 - column 4, line 10; figure 3 --	1
A	GB, A, 2183348 (MANCHESTER LASERS LTD) 3 June 1987 see abstract; figures 3,4 --------	4

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search 31st July 1989	Date of Mailing of this International Search Report 12. 09. 89
International Searching Authority EUROPEAN PATENT OFFICE	Signature of Authorized Officer T.K. WILLIS

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 8900426

SA 28295

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A- 0122899	24-10-84	US-A- 4639674	27-01-87
		DE-A- 3474072	20-10-88
US-A- 3932813	13-01-76	CA-A- 984463	24-02-76
		CH-A- 558532	31-01-75
		DE-A- 2319927	31-10-73
		FR-A,B 2181078	30-11-73
		GB-A- 1386035	05-03-75
GB-A- 2183348	03-06-87	None	

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